DISCUSSION

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Solar Energy and the Public Interest

Americans need to know more about what solar energy can do, how its exploitation can affect our national well-being, and why it is essential that it be generously publicly funded now. We are not doing our fair share as a developed nation.

In October, 1997, the BEW-Swiss Federal Office of Energy and divisions of Switzerland's Paul Scherrer Institute, the Tokyo Institute of Technology, and Israel's Weizmann Institute of Science sponsored an International Symposium on Solar Chemistry. More than 100 scientists and engineers from 14 countries attended. They were interested in solar driven processes for the production of energy carriers, manufacture of industrial chemicals, reduction of greenhouse gas emissions, and destruction of toxic wastes. As part of the program, the Paul Scherrer Institute dedicated a new concentrating solar research reactor which will be used, in cooperation with other similar facilities in Europe and Israel, to develop industrial processes powered by sunlight. The papers presented there revealed that the United States lags far behind other developed countries in this important area. Although many scientist-engineers who have studied in the U.S. attended the Symposium, the most productive of them were working outside the U.S.

On my return to the U.S., I spoke about it with friends and colleagues, many of whom are scientists and engineers who do energy related research. I was surprised to learn that many of them don't know that solar energy can be used for things other than heating water and houses and generating electric power. It's important that Americans, especially industrial and public policy decision-makers, know more. It's important that we launch, now, a substantial national effort and participate in the international effort to develop technologies that exploit the remarkable advantages that solar energy can provide in addressing global energy problems.

What, besides comfort heating and electricity, can solar energy provide?

- Concentrated sunlight can increase the energy content of fossil fuels, wood, and crop residues by using them to produce hydrogen and other enriched high-energy fuels, as well as feedstocks (raw materials) for the chemical industry, and can reduce greenhouse gas emissions associated with their use.
- Concentrated sunlight can be used to increase our usable reserves of fossil fuels by eliminating a serious environmental impediment associated with their use.
- Concentrated sunlight can be used directly to supply clean heat for high-temperature processes at temperatures higher than those which can be achieved in nuclear reactors or by burning fuels. It can therefore reduce (and sometimes even eliminate completely) the amount of electrical energy customarily used for some industrial processes, such as the production of zinc or aluminum.

How can sunlight increase the energy content of existing fuels?

Cellulose has been steam gasified (changed into synthesis gas, a high-energy fuel and feedstock for the chemical industry) in a concentrating solar furnace at the University of Minnesota. Natural gas (methane) has been reformed by reacting it with carbon dioxide in a similar furnace at Israel's Weizmann Institute. Almost any carbonaceous fuel—coal, coke, crude oil, natural gas, wood, crop residues, or even garbage—can be made to react with hot steam to produce hydrogen as well as the mixtures of hydrogen with carbon monoxide we call synthesis- or water-gas. This industrial steam reforming technology is more than a century old. It was used with coal and coke to produce the domestic illuminating and fuel gases that were piped into our homes and factories more than 100 years ago. We can burn them as energy-enriched, synthetic fuels, if we choose, or use them as feedstocks, to produce valuable industrial chemicals, including methanol and other liquid fuels.

Gasification and reforming use a lot of heat. That heat is supplied now by simply burning a substantial fraction of the fuel. That fraction need not be burned. In steam-gasifying fuels with sunlight, we increase their heating values by as much as 45 percent and reduce substantially the amount of the greenhouse gas, carbon dioxide, that we add to the atmosphere to achieve our objective. When sunlight supplies the heat, we store solar energy in the product and recover it later, at our convenience, when we burn the energy enriched gas or use it to produce liquid fuels or industrial chemicals. Incorporating a cycle to cogenerate electricity as part of the gasification process could make one ton of coal do the work of several.

How can solar energy be used to increase our usable reserves of fossil fuels?

Natural gas, petroleum, and coal all contain varying amounts of sulfur which must be removed before they are burned or scrubbed from stack gases afterwards. The sulfur found in natural gas and petroleum is usually sequestered and recovered as hydrogen sulfide, an extremely toxic industrial waste, which is disposed of at the refinery by partially burning it in air. The hydrogen component is burned and the sulfur is recovered and sold. The stack gas from the burning process consists mostly of nitrogen from the air contaminated with acidic oxides of sulfur. These contaminants are irritants and a major contributor to the formation of acid rain. They must be removed before the nitrogen can be returned to the atmosphere. Cleaning up stack gas is costly. For this reason, fossil fuel deposits with high sulfur contents are used sparingly or simply left in the ground. But hydrogen sulfide can be split into hydrogen and sulfur by simply heating it in the absence of air to recover both hydrogen and sulfur. Sunlight has been used to convert the toxic industrial waste, hydrogen sulfide, into two valuable commodities, hydrogen and sulfur, in a solar research furnace. No hydrogen need be burned. No air need be introduced. There are no large amounts of refinery stack gas to be cleaned up. Sulfur in fossil fuels need not be so great an impediment to their use. Fuel deposits containing more sulfur can become profitable and therefore usable. Thus, thermal splitting of hydrogen sulfide could substantially increase our usable reserves of petroleum, natural gas, and coal.

There are yet other benefits. Refineries, having burned the hydrogen in their hydrogen sulfide, often have to buy back hydrogen on the market to get the hydrogen they need to convert their crude oil into gasoline. The heating value of the hydrogen recovered in the solar process is about three times the solar heat needed to produce it from hydrogen sulfide. A concentrating solar furnace that splits hydrogen sulfide, using energy from the sun, a distant thermonuclear energy source whose most hazardous radiation can be blocked by suntan oil, produces more fuel than it uses. At the risk of being accused of immodestly taking credit for having already achieved a holy grail now being sought by my atomic energy competitors, I like to refer to it as a perfectly safe thermonuclear breeder reactor.

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How can solar energy help us avoid the wasteful, inefficient intermediate step of using fuel to produce the electrical energy now being used in many industrial processes?

Solar energy can be used to replace electrical heating for very-high-temperature processing. At the University of Minnesota solar heat has been used as a substitute for part of the electrical energy needed to electrolyze zinc oxide to produce zinc as well as to smelt zinc oxide with carbon, using no electrical energy at all. Researchers at the Weizmann and Paul Scherrer Institutes are conducting studies of the direct reduction of zinc oxide by carbon and hydrocarbons, using solar energy as the heat source.

Many industrial processes use large amounts of process heat which must be added at temperatures too high to be maintained in nuclear reactors or by burning industrial fuels. They use commercial electric power to supply the heat needed to maintain the high temperatures. In all electric power plants, solar as well as conventional, one-half to two-thirds of the heat used by the power plant becomes waste heat which is rejected to the surroundings. That energy never gets to the place where it's needed. Concentrated sunlight, however, can replace all of the electrical energy needed to keep the temperature high. More demanding processes, such as the production of aluminum, must now use some additional electrical energy, no matter how they are heated. In such processes, the amount of electrical energy needed goes down as the temperature sustained by the heat source goes up, and sunlight can produce and sustain temperatures many hundreds of degrees higher than nuclear reactors or the combustion of fossil fuels can. Solar heated furnaces have been used to produce refractory nitrides and carbides—energy intensive versatile ceramics, abrasives and energy carriers—substances that are now produced at high temperatures in electrically heated furnaces.

Given all the advantages I've mentioned one might well ask, ''Why isn't industry interested in exploring and developing solar energy processing now?'' There are several important reasons. One is that sunlight is intermittent and industry prefers continuous processes. Another, for the time being at least, is that fossil fuels are so cheap that unsubsidized sunlight can rarely compete with them. The most important reason, however, is that industry is already using processes in plants that have evolved over the past 100 years. They are proven winners and represent enormous capital investments in facilities which have long lifetimes. It should be feasible to continue to use those processes in association with the solar energy source. We can do that by learning to mate reactors with the solar source and to bank them, or by modifying their operation to store extra energy while the sun is shining so that the plant will not be idle when the sun is not shining.

What's the rush?

Because it takes about 50 years to reconstruct a major technology, it is important that we develop solar technological know-how now so that, when the appropriate times come, we will have the option, of making a gradual, composed transition to solar energy. The task of mating the various industrial processes with solar energy will not be simple, but it will be technically easier than many other scientific and engineering feats we have accomplished after we made them national objectives.

A reasonable person might ask, ''But why not just let the market control the development of solar energy as it's needed?'' The answer is that it's not likely that this development can ever be undertaken by unsubsidized industry, constrained as it is by short range economic considerations. Nevertheless, if we become reluctant to use nuclear energy for any reason, or if taxes and limitations on the use of fossil fuels are mandated by concern about a greenhouse effect, or even if they become more costly, the increased use of solar energy will be unavoidable. Energy is fungible. Figuratively, all the world's prime energy suppliers stock a global reservoir; users deplete it. Those who add to the reservoir or slow its depletion by practicing conservation reduce the cost of energy; those who take from it raise its cost to all. The 1973 OPEC embargo caused global panic and precipitated abrupt, extensive emergency conservation efforts. The most serendipitous beneficiaries of the ensuing drop in the price of petroleum have been those who use the most petroleum. Those who, at their own expense, practiced conservation and developed alternative energy sources made possible the windfalls to those who didn't. But the conservationists and alternative energy users can, and sometimes do, experience economic disaster because, when the cost of alternatives approaches the price of petroleum, the price of petroleum can easily be cut enough to drive them out of the market. Thus, there is no incentive for unsubsidized private industry to develop solar alternatives.

What's in it for us as a nation?

Experience has shown that our country has benefited from prompt public development of worthwhile projects that unsubsidized private enterprise cannot afford to undertake. The industrial and scientific preeminence, prosperity, standard-of-living, and strength of the United States depend on federal support of enterprises such as education, transportation, a postal system, and a strong defense establishment. None of them were self-supporting in their beginnings, nor were they expected to be, though some have become so. It would be unthinkable to eliminate universal educational opportunities because schools may not be demonstrably cost effective; nor do we want our army, as a condition for its existence, to prove that it can operate at a profit.

We have seen that concern about energy can lead to a loss of freedom of action by nations, to harmful international alliances and rivalries, and to war. We face a global challenge that is best addressed by vigorous national efforts and international cooperation. Nations need freedom of action short of war to assure that their people will continue to enjoy the things that contribute to high standards of living and to ensure that these benefits can become available in those nations that do not now have them, so that they are not tempted to resort to violence to get them. It is in our national as well as global interest to start *now* to contribute our fair share to the international effort to make possible a smooth, gradual, comprehensive, but non-disruptive, transition of industrial processing to the *direct* use of sunlight rather than electrical or fossil energy as it becomes advantageous or necessary to do so.